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Food Habits and Growth of Rainbow Trout in a Prairie Pond

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FOOD HABITS AND GROWTH OF RAINBOW TROUT

IN A PRAIRIE POND

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science, and is acceptable for meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor

Head, Department of
Wildlife and Fisheries Sciences

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IN A PRAIRIE POND

Abstract

Ronald Marvin Koth

Rainbow trout (Salmo gairdneri) were introduced into Lower Abbey Pond, South Dakota, at a stocking rate of 772/ha in June 1977. Sampling was begun in January 1978 to determine food habits and growth of the fish. Trout and environmental samples were taken at 10 day or monthly intervals depending upon the season. A linear index of food selection was calculated and growth data was analyzed using the SHAD computer program.

Food habits were determined for 159 rainbow trout collected from January 1978 to October 1978. Stomachs contained a total of 5,700 food organisms with the major constituents by number being notonectids (35.0%), dipteran larvae (31.2%), corixids (7.0%), and fathead minnows (Pimephales promelas) (1.2%). Volumetrically, notonectids comprised 37.7% of the total volume of organisms, fathead minnows 16.8%, dipteran larvae 9.9%, and decapods 8.1%.

Growth of the trout was better than in many areas of the country and was closely comparable to other trout ponds in the region.

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INTRODUCTION

The majority of the trout fishing opportunities available in South Dakota are concentrated in the western region of the state, primarily in the Black Hills. Because of the lack of suitable stream habitat and the shallow nature of the majority of the lakes and ponds few trout fishing opportunities exist in eastern South Dakota.

The purpose of this study was to evaluate an eastern South Dakota pond for its potential as a possible recreational trout fishery by determining the food habits and growth of stocked rainbow trout (*Salmo gairdneri*).

Lower Abbey Pond near Marvin, South Dakota, was selected as the site for the study. Selection was based upon characteristics this pond had in common with ponds used successfully in central Canada for rainbow trout fisheries by Johnson and Hasler (1954), Fraser (1972), and Ayles et al. (1976). Characteristics conducive to rainbow trout survival and growth were: 1) a relatively deep pond to minimize the potential of summerkill and winterkill, and 2) a recently filled pond to minimize the possibility of the presence of large predator fishes and also to reduce competition with large numbers of small fishes.

Since prairie ponds do not offer the proper conditions for natural reproduction of rainbow trout (Vestal 1943; Coble 1961), a periodic stocking schedule would have to be implemented to maintain the fishery. Miller and Thomas (1956) found that along with periodic stockings, a periodic renovation program also had to be employed to maintain angler yields and growth rates at acceptable levels. They found that first year trout plantings were harvested at up to 80% of stocking rate, but in subsequent years of stocking catch rates declined from 50% to 0%, indicating that established trout populations reduced recruitment into populations from stockings.

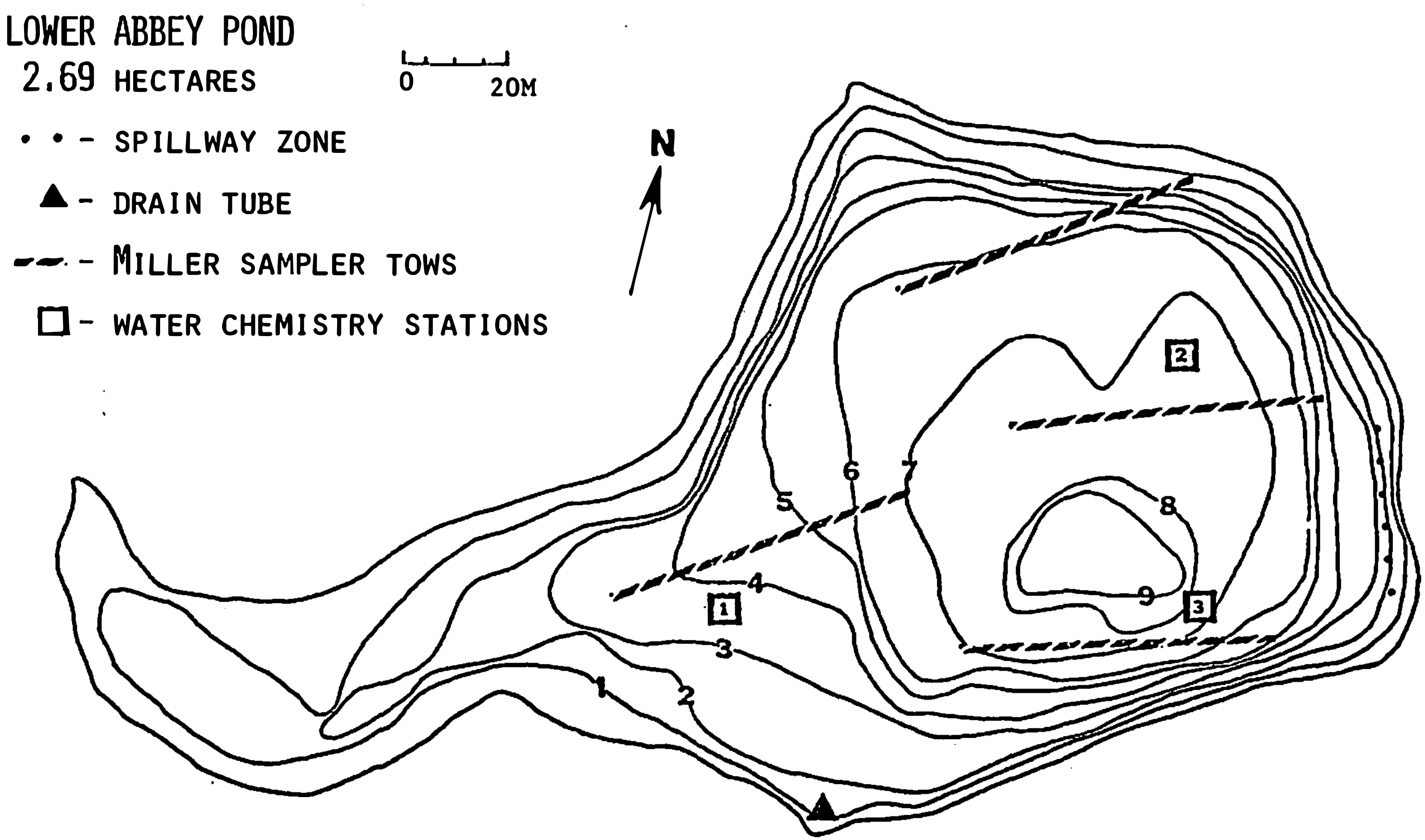
Several other studies have shown that rainbow trout can be grown to a recreationally usable size in ponds in 1 or 2 growing seasons (Johnson and Hasler 1954; Miller and Thomas 1956; Meyers and Peterka 1976). Even though prior studies on ponds similar to Lower Abbey Pond have shown that rainbow trout can be grown to a recreationally usable size, variations in climatic conditions, pond characteristics, etc., make it necessary to regionalize research of this nature.

STUDY AREA

Lower Blue Cloud Abbey Pond near Marvin, South Dakota, is owned and administered by Blue Cloud Abbey Monastery and is located on the eastern edge of the Coteau des Prairies in Grant County. The Coteau des Prairies is a glacial plateau typified by chernozem soils and a cool moist climate (Westin et al. 1967). The pond lies in R50W, T121N, S35 and was filled via runoff and seepage from Upper Abbey Pond in the spring of 1977. Average temperature for the region is 7.1 C but extremes vary from -35.5 C to 42.2 C (Radant 1975). Average annual precipitation is between 50.8 cm and 55.9 cm. The pond (Figure 1) was originally designed as an irrigation reservoir but during the study period no water was removed for that purpose; the pond was used primarily for stock watering and recreation. The pond has an area of 2.69 ha and is surrounded by a watershed used primarily for pasture with some small grain cropland. Vegetation along the shoreline consists of grasses, willows, and a few Russian olive trees. The face of the dam is granite riprap to prevent wave action erosion. Clay, sand, and silt comprise most of the pond bottom. A grass-covered spillway is located near the southeast corner of the pond and an overflow tube is located at the southwest end of the riprap of the dam.

Physical characteristics of the pond include: shoreline length 657 m, shoreline development 113, maximum depth 9.75 m, mean depth 4.21 m, and volume 113,246 m^3. Ranges of other physicochemical properties of the pond during the study period were dissolved oxygen from 0 mg/1 to 17.2 mg/1, temperature from 1.0 C to 26.0 C, pH from

Figure 1. Location of sampling stations, Miller sampler tow routes, and depth contours (in meters), of Lower Abbey Pond, South Dakota, 1978.



6.1 to 9.6, total alkalinity from 110 mg/l to 220 mg/l, total hardness from 140 mg/l to 240 mg/l, conductivity from 374 μmhos to 548 μmhos, and secchi disk visibility from 55.9 cm to 152.4 cm (Appendices 1 and 2). These limnological data are within the ranges of similar data reported by Schmidt (1967) for lakes in eastern South Dakota and by Radant (1975) for Upper Abbey Pond.

METHODS

Lake area was determined using a microptic alidade, plane table, and compensating polar planimeter. Bottom contours were determined by running timed transects (Lind 1974) with an echo sounding device during spring 1977. Zooplankton, benthos, meter net, water samples, and rainbow trout were taken on each sampling date which were at 10 day intervals except during August, September, and October, 1977 and January, February, and March, 1978 when monthly samples were taken. No meter net samples were taken during May 1978. Three locations in the pond (Figure 1) were sampled for water analysis. Station 1, the shallow area of the pond, had a mean water depth of 3.4 m, Station 2, the deep area of the pond in the northeast corner, had a mean water depth of 7.2 m, and Station 3, the deep area of the pond in the southeast corner of the pond, had a mean water depth of 7.7 m. A secchi disk was used to obtain an index of water clarity. Water temperatures and conductivities were measured with a YSI Model 33 S-C-T meter. Conductivity readings were standardized and are reported at 25 C. Water samples for dissolved oxygen analysis were collected at 2 m intervals with a Kemmerer water bottle and O_2 was determined using the azide modification of the Winkler process (APHA 1971). Total alkalinity and hardness were measured using a Hach DR-EL 1206-00 kit.

Zooplankton samples were obtained by making 4, 60 m oblique tows (Figure 1) with a metered Miller sampler equipped with 153 μ netting. Samples were preserved in Lugol's solution and diluted to fixed volumes.

Three 1 ml subsamples from each tow were counted in a circular counting wheel (Ward 1955).

Benthic samples were taken with a 229^3 mm Eckman dredge. Ten random samples were taken and combined to form a composite sample for each sampling date. Benthos was initially preserved in 10% formalin and later transferred to a 70% solution of isopropyl alcohol with 10 mg of rose bengal per liter of solution for staining (Mason and Yevich 1967). All organisms in each composite sample were counted to determine the number of organisms per m^2.

Meter net tow samples to capture nektonic organisms were collected with 60 m tows along 3 shoreline areas at night using a net of 571 µ netting. Total number of organisms in each sample were counted to determine number of organisms per liter.

Two-thousand-seventy-five (772/ha) rainbow trout were stocked on 7 June 1977. Trout ranged from 85 to 110 mm and 6.3 to 13.9 g and averaged 98.0 mm and 9.2 g. The fish appeared to be in good condition and immediately began feeding-like behavior at the water surface. No dead fish were observed after stocking or during the study. No estimate of stocking mortality was made but Lawler et al. (1974) reported that in Canadian lakes initial stocking mortality (first 2-16 days) was low. In addition to the trout, 400 walleye (Stizostedium vitreum) fry were stocked during June 1977.

Beginning in January 1978 stomach samples were taken. Trout were captured during January, February, and March by hook and line fishing. During the remainder of the study period hook and line fishing and night gill net sets were used for capture. The final sample in October 1978 was obtained by applying 1 mg/l rotenone to the pond.

Smith (1959) and Carlander (1969) have reported night gill net sets had maximum efficiency for rainbow trout capture. Two 22.9 x 2.4 x 0.19 m gill nets and 3, 30.5 x 6.1 m gill nets of 19.1, 25.4, and 32.0 mm (bar mesh) were used. Trout were killed immediately upon capture to avoid food regurgitation (Turner 1955) and preserved in 10% formalin. The digestive tract anterior to the pyloris was utilized in food habitat determination. Total lengths and weights were recorded to the nearest 1.0 mm and 1.0 g respectively. Scale samples were taken from the area just below and anterior to the anterior portion of the dorsal fin. Scale impressions were made on acetate strips and read on an Eberbach scale projector. Injested food organisms were identified and counted with the aid of 45x binocular and 400 x compound microscopes.

Selection by rainbow trout of available benthic and nektonic organisms was determined by use of the linear index of food selection as described by Strauss (1979). The linear index of food selection is calculated by the formula:

$$L = r_i - p_i$$

Where L is the linear index of food selection, r_i is the relative abundance of the prey item in the digestive tract expressed as a percentage of the total digestive contents and p_i is the relative quantity of the same prey item in the environment expressed as a percentage. L values range from -1 to +1, with positive values indicating preference and negative values indicating avoidance or inaccessibility. The expected value of the index for random feeding is zero for all conditions. Extremes occur only when the prey item is rare but consumed almost exclusively, or is very abundant but is rarely taken.

The SHAD computer program was used for age and growth analysis (Mayhew 1970). The portions of the SHAD program used in analysis for this study were length-frequency distribution, body condition factor [K(TL)], body-scale regression, and back calculation of body length at the end of each year of life. Because fish were captured during the months of January through April before an annulus had been formed, the outer scale margin was assumed to be the location of the first annulus; fish collected from May through October had a detectable annulus. Annuli of rainbow trout have been reported to form from April to June (Brown and Holton 1953; Greeley 1953). Particulars of the methods of calculation for each of the previous factors can be found in the preface to the program.

RESULTS AND DISCUSSION

Food Habits

Food habits were determined from 159 rainbow trout collected from January 1978 to October 1978. Percent number per stomach, frequency of occurrence, and volume were determined for each food organism (Table 1). Stomachs contained a total of 5,700 food organisms with a total volume of 534.0 ml.

Insects Versus Other Organism Usage

The results of this study indicated that 96.6% of the total number and 63.5% of the total volume of organisms found in trout stomachs were insects. Notonectids comprised the most numerically abundant (35.0%) group of organisms in the trout diet, dipterans ranked second (31.2%), corixids ranked third (7.0%), and fathead minnows (*Pimephales promelas*) ranked fourth (1.2%).

Notonectids comprised the largest volume (37.7%) of food organisms with fathead minnows ranked second (16.8%), dipteran larvae third (9.9%), and decapods fourth (8.1%). Zooplankters were not found in any trout stomachs sampled during this study.

Insects were also found to be most abundant numerically (52.7%) and volumetrically (61.9%) by Meyers (1973), while amphipods and limnetic crustaceans comprised the remainders from 153 rainbow trout stomachs. Wurtsbaugh and Brocksen (1975) determined that insects comprised 5.8% by number and 99.4% by volume of 136 rainbow trout; the remainders were composed of limnetic crustaceans. Carline et al. (1976) reported that

Table 1. Stomach contents of rainbow trout (Salmo gairdneri) from Lower Abbey Pond, 1978, expressed as percent number per stomach and percent volume per stomach (in parenthesis).

	Date																	
Food item	1-5	2-16	3-17	4-27	5-12	5-23	6-1	6-6	6-13	6-23	7-14	7-25	8-4	8-15	8-29	9-8	9-29	10-11
Annelida																		
Hirudinidae							2.9 (15.6)											
Amphipoda																		
Gammarus					T[1] T	T T												
Decapoda																		
Orconectes							T (12.1)		T (49.2)	1.7 (20.1)	66.6 (91.5)							
Hydracarina	7.1 T				T T	2.5 T	2.7 T	T T										
Hemiptera																		
Corixidae	45.7 (5.8)		7.6 (2.4)	4.5 (3.4)	15.1 (13.5)	T T	T T	38.0 (4.9)	50.8 (4.0)									
Notonecta				3.9 (8.4)	T T					3.4 T								85.4 (85.1)
Buenoa					22.2 (25.2)			2.8 T										9.2 (4.0)
Coleoptera																		
Haliplidae					7.2 (3.4)	1.2 T	1.0 T		T T									
Dytiscidae	1.4 T		11.5 (8.6)		4.5 (9.5)	T T				1.7 T		50.0 (60.3)						4.4 (3.9)
Hydrophilidae					3.4 (3.9)													

Table 1. Continued

Food item	1-5	2-16	3-17	4-27	5-12	5-23	6-1	6-6	6-13	6-23	7-14	7-25	8-4	8-15	8-29	9-8	9-29	10-11
	Date																	
Carabidae					1.3 (1.5)	T T												
Eucnemidae					1.6 (1.6)	T T												
Elmidae					T T													
Curculionidae					T T													
Chrysomelidae					T T													
Gastropoda																		
Physidae	1.4 T				T T				T T	1.7 T								
Lymnaeidae			3.8 (1.8)															
Pelecypoda																		
Sphaeriidae							1.9 T		2.0 (1.5)			50.0 (39.7)						
Diptera																		
Culicidae				3.5 (6.2)	3.6 (7.7)	27.9 (52.2)	5.1 (3.6)		1.3 (1.6)									
Chaoborinidae						5.3 (1.0)	19.8 (1.5)	38.0 (1.1)	54.6 (6.7)	16.9 T								
Chironomidae	18.6 (2.2)	38.1 (1.9)	69.2 (19.9)	87.1 (60.9)	38.4 (31.5)	60.9 (44.2)	58.2 (16.1)		28.8 (12.9)	1.7 T								

Table 1. Continued

	Date																	
Food item	1-5	2-16	3-17	4-27	5-12	5-23	6-1	6-6	6-13	6-23	7-14	7-25	8-4	8-15	8-29	9-8	9-29	10-11
Fishes																		
Yellow perch		4.8 (7.5)						17.6 (54.9)		18.6 (40.9)								T (6.8)
Fathead minnow	25.7 (91.2)	57.1 (90.5)	7.7 (67.2)	T (20.9)			5.9 (49.5)	2.8 (39.3)	1.6 (22.8)	3.4 (33.3)	33.3 (8.4)							
Sample size	23	11	6	5	16	18	15	7	15	13	2	2	1	2	0	0	0	14
No. fish w/food in stomach	18	9	6	5	16	18	13	7	15	13	2	2	1	1	0	0	0	14
Avg. no. food items/stomach	3.8	2.3	4.3	40.4	89.1	40.0	28.7	20.3	19.9	4.5	1.5	1	1	1	0	0	0	168.3
Avg. vol. food items (ml) each stomach	1.1	1.5	.5	1.9	3.6	1.8	3.4	6.5	1.5	2.1	5.9	.07	5.4	5.4	0	0	0	16.9

[1] T = Trace

insects comprised 31.2% of the total number of organisms with the remainder comprised primarily of other types of benthic invertebrates, fish, and limnetic crustaceans.

Notonectids comprised the largest number and volume of organisms eaten by trout in Lower Abbey Pond. This may be misleading, though, as all notonectid usage was restricted to the sampling when the pond was being poisoned. Prior to that sampling notonectids were not found in trout stomachs or environmental samples. Potential abnormal activity of the trout and notonectids, induced by the rotenone, may have affected notonectid usage.

Dipteran larvae, ranked second in total numbers consumed by trout, could be described as the most numerically utilized organism if notonectids were ignored. Dipteran larvae were found in trout stomachs throughout the sampling period and were also the most abundant organism found in environmental samples in Lower Abbey Pond. The resistance of dipteran larvae to low dissolved oxygen levels (Pennak 1978) may have caused them to remain more evenly distributed throughout the pond and thus more available to foraging trout than other organisms which were restricted to pond zones with sufficient dissolved oxygen.

High numerical abundance and volume results for fathead minnows may have been affected by the number of trout collected from January through April versus the number of trout taken during May through October samples. Thirty-seven percent of the total number of trout taken were captured during the period from January through April, and of the trout taken during that time, fathead minnows were found with a mean frequency of 45.2%. The May through October samples only had a mean frequency of occurrence of 4.2% for fatheads. January through April samples also had a mean percent number per stomach of 22.6% and a mean percent volume per stomach of 53.0%, while May through October samples had a mean percent number per stomach of 3.4% and a mean percent volume per stomach of 14.7% for fatheads.

Trout may have utilized fathead minnows during the colder months rather than other organisms because the fatheads were larger and more satiating or because they were more available. Benthic organisms may have been less available during this time because of oxygen depletion near the bottom of the pond, although Carlander (1952) reports that fishes will forage for short time periods in oxygen depleted zones. Serns (1976) also reported that oxygen depleted layers of water in a pond do not restrict fish movement through those layers.

Carline et al. (1976) reported that benthic organisms, mudminnows (Umbra limi), and sticklebacks (Culaea inconstans) were numerically the predominant food items of trout in northern Wisconsin ponds, and if food items had been evaluated by weight, forage fishes would have ranked among the most important foods. Burdick and Cooper (1956) reported that in Weber Lake, Wisconsin, minnows were abundant in trout stomachs during some years but of minor importance during others. They also stated that during some years of excellent growth trout did not feed extensively on minnows, indicating that minnows were not required for good growth. The results of the present study, showing heavy utilization of fathead minnows during January through April implies that stocking fathead minnows with rainbow trout or trout stockings into ponds with fatheads already present may be helpful in promoting trout growth.

Aquatic Versus Terrestrial Organism Usage

Aquatic organisms comprised 98.4% of the total number and 99.3% of the total volume of food organisms; the remainders were comprised of terrestrial organisms. During a 6 year study Leonard and Leonard (1946) found that aquatic organisms comprised 81.2% of the total number, and 73.0% of the total volume of food organisms found in 322 rainbow trout stomachs in Birch Lake, Michigan. Meyers (1973) reported that virtually 100% of all recognizable organisms from 153 rainbow trout stomachs collected from 4 prairie pothole lakes in North Dakota were aquatic. Wurtsbaugh and Brocksen (1975) reported that in Castle Lake, California, during July-September, 136 rainbow trout consumed 97.7% aquatic organisms and 2.3% terrestrials by number and 85.0% aquatics and 15.0% terrestrials gravimetrically. In contrast to the previous data, Swift (1970) reported that in Castle Lake, California, during 1963-65, 275 rainbow trout depended upon terrestrial organisms for 55.9% of their total energy intake while aquatics comprised 44.1%.

The predominance of aquatic organisms in the diet of rainbow trout from Lower Abbey Pond was probably influenced by the fact that trout in ponds have a tendency to utilize aquatic organisms more extensively than trout in streams. Metzelar (1928) reported that 224 rainbow trout in Michigan streams consumed 35.0% terrestrial organisms by number. Clemens (1928) found that 83 rainbow trout up to 25.4 mm in length from streams in Oneida County, New York, consumed an average of 28.5% terrestrial organisms by volume with 65.0% of the total food volume of 10.2-15.2 mm rainbow trout comprised of terrestrial organisms. Hynes (1970) stated that the diet of rainbow trout in streams during the summer may be comprised of 40-50% terrestrial organisms.

The lack of overhanging vegetation surrounding Lower Abbey Pond and the corresponding paucity of terrestrial insects falling into the pond may have contributed to the predominance of aquatic organisms in the trout diet. Aquatic organisms also predominated in the environmental samples taken from the pond (Table 2) but sampling specifically for terrestrial organisms was not conducted.

Seasonality

Food organisms found in trout stomachs varied considerably from one sampling date to another (Table 1 and Table 3). Dipteran larvae (31.2%), corixids (7.0%), and fathead minnows (1.2%) were numerically the most important organisms throughout the study except during August and October when decapods (100%) and notonectids (85.4%) were prevalent. Volumetrically, fathead minnows (16.8%), dipteran larvae (9.9%), and decapods (8.1%) were most important throughout the study except during August and October when decapods (100%) and notonectids (85.0%) were most important. Overall notonectids comprised 35.0% of the total number and 37.7% of the total volume of organisms found in trout stomachs.

The largest number of stomachs were examined during May and June (59.0%) and the greatest diversity of organisms was also found during this period. Terrestrial organisms were found in stomachs in greater numbers during May and June than during any other period.

Table 2. List of organisms found in rainbow trout (Salmo gairdneri) stomachs or environmental samples in Lower Abbey Pond, 1978.

Aquatic organisms	Terrestrial organisms
Annelida	Hymenoptera
Oligochaeta*	Braconidae*
Hirudinidae	Hemiptera
Amphipoda	Cormelaenidae*
Gammarus*	Lepidoptera*
Decapoda	Coleoptera
Orconectes	Eucnemidae
Hydracarina	Carabidae*
Cladocera	Endomychidae*
Daphnia galeata*	Staphylinidae*
Plecoptera*	Heteroceridae*
Ephemeroptera*	Pselaphidae*
Odonata*	Scarabaeidae*
Hemiptera	Curculionidae*
Notonecta	Chrysomelidae*
Buenoa	Elmidae*
Corixidae	
Coleoptera	
Gyrinidae*	
Halpidae	
Hydrophilidae*	
Dytiscidae	
Diptera	
Culicidae	
Chaoborinae	
Chironomidae	
Gastropoda	
Physidae	
Lymnaeidae	
Planorbitae*	
Pelecypoda	
Sphaeriidae	
Percidae	
Perca flavescens	
Cyprinidae	
Pimephales promelas	

* Less than 1% of total number on any date.

Table 3. Percent occurrence of food organisms of rainbow trout (Salmo gairdneri) in Lower Pond, 1978.

Food item	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.
Hirudinidae						4.2				
Gammaris					5.8					
Decapoda						4.2	50.0	100.0		
Hydracarina			5.6		11.8	6.3				
Corixidae	33.3		44.4	20.0	52.9	56.3				
Notonecta				20.0	2.9	4.2				100.0
Buenoa					2.9	4.2				64.3
Halpidae					44.0	8.3				
Dytiscidae	16.6		5.6		35.3	2.1				100.0
Hydrophilidae					23.5		25.0			
Culicidae				40.0	64.7	6.3				
Chaoborus					14.7	29.2				
Chironomidae	50.0	22.2	11.1	60.0	52.9	22.9				
Physidae			5.6		2.9	4.2				
Sphaeriidae						6.3	25.0			
Lymnaeidae	16.6									
Carabidae					20.6					
Eucnemidae					11.7					
Elmidae					11.8					
Curculionidae					8.8					
Chrysomelidae					2.9					7.1
Fathead minnow	33.0	66.6	61.1	20.0		18.8	25.0			
Yellow perch		11.1				6.3				42.8
Total stomachs	18	9	6	5	34	48	4	2	0	14

Dipteran larvae comprised 18.0 to 70.0% of the number of organisms in the trout stomachs from January through June. Dipteran larvae were not found in stomach samples during the period July through October.

Corixids comprised 5.0 to 45.0% of the number of organisms in the trout stomachs from January through June; following this period none were found in trout stomachs. Fathead minnows were found in trout stomachs during the period January through April and in June and July. The highest percent occurrence of fatheads in the trout stomachs was in February (66.6%); the lowest was during June (18.8%).

The greater diversity and larger numbers of terrestrial organisms during May and June may be partly explained by high water levels which could have facilitated the chance presence of more terrestrial organisms in the water as they dropped off flooded vegetation. Late spring and early summer are also periods when terrestrial organism abundance usually increases. Dipteran larvae abundance (by number) in the trout diet may be partially explained by the abundance of benthic dipterans and because rainbow trout have been reported in some cases to exhibit a preference for benthic organisms (Meyers 1973; Carline et al. 1976). Fathead minnows were found in trout stomachs primarily during the time when ice cover was present or when surface water temperatures were below 11 C. During July only 4 trout were collected for stomach analysis and only 1 of those fish had eaten fatheads so the 25.0% frequency of occurrence figure for July is possibly misleading concerning fathead usage. Trout may have eaten more fatheads during the period of colder water temperatures because fatheads were more readily available or because they were preferred by the trout during that time.

Food Selection

One-hundred-thirty benthic and 24 meter net samples collected during the study period were used to determine seasonal trends in the aquatic invertebrate population (Table 4 and Table 5). Chironomidae, Sphaeridae, and Oligochaeta were the taxa contributing to the summer peaks in the benthos samples, while Chaoborus, Hydracarina, and fathead minnows were the taxa contributing to the summer peaks in the meter net samples. The greatest number of benthic organisms recorded was $2,116/m^2$ in June. The greatest number of organisms in the meter net samples was also in June (.01/1). Buscemi (1961) found high numbers of organisms occurred during the spring in pond environments. Overall abundance of invertebrates followed the same pattern as the summer peaks with Chironomidae, Sphaeridae, and Oligochaeta most numerous in the benthos and Chaoborus, Hydracarina, and fathead minnows most numerous in the meter net samples. Numbers of other organisms were low.

Linear food selection indices were calculated for benthic organisms for May through October and for June through September for nektonic organisms (Table 6). No results are given for August through September because of the small number of fishes sampled. Food selection indices were not calculated for those organisms that were found during only 1 sampling period or in only 1 or 2 trout stomachs. Thus, many organisms that were found only occasionally in trout stomachs or environmental samples do not have calculated selection indices. The unrealistic values of +1 and -1 were avoided by disregarding occasional occurrences when calculating selection indices. The extremes of +1 and -1, do not

Table 4. Organisms in meter net tows, density per liter and percent composition (in parenthesis) in Lower Abbey Pond, 1978.

Organism	6-5 org/l	6-5 % comp.	6-12 org/l	6-12 % comp.	6-22 org/l	6-22 % comp.	7-24 org/l	7-24 % comp.	8-3 org/l	8-3 % comp.	8-14 org/l	8-14 % comp.	8-29 org/l	8-29 % comp.	9-28 org/l	9-28 % comp.
Decapoda			.00002	(00.50)												
Gammaris			.00002	(00.12)	.0002	(1.38)	.00002	(00.087)								
Hydracarina	.003	(66.70)	.009	(51.40)	.009	(82.60)										
Plecoptera			.00001	(00.12)					.00001	(00.33)						
Ephemeroptera	.00004	(00.98)	.00008	(00.50)					.00001	(00.33)						
Corixidae	.00012	(2.70)	.002	(11.60)	.0005	(4.23)					.00001	(00.35)				
Dystiscidae															.0002	(5.53)
Gyrinidae	.00001	(00.25)														
Halpidae	.00001	(00.25)			.0004	(00.40)			.00001	(00.33)			.00001	(00.02)		
Chaoborus	.00054	(12.50)	.003	(16.90)	.0005	(4.72)	.0244	(99.50)	.0026	(81.00)	.003	(98.90)	.053	(99.90)	.0025	(93.30)
Chironomidae			.00004	(00.25)												
Adult Diptera	.0004	(00.98)	.00002	(00.12)	.00001	(00.09)					.00002	(00.70)	.00001	(00.02)	.00003	(01.19)
Physidae			.00008	(00.50)												
Lepidoptera	.00001	(00.25)														
Yellow perch			.00006	(00.37)	.0001	(1.30)	.00007	(00.30)	.00034	(11.00)						
Fathead minnow	.0007	(15.40)	.003	(18.00)	.0006	(5.31)	.00003	(00.13)	.0002	(7.60)			.00003	(00.06)		
Total	.006	(100.00)	.017	(100.00)	.011	(100.00)	.025	(100.00)	.003	(100.00)	.003	(100.00)	.053	(100.00)	.003	(100.00)

Table 5. Organisms in benthic samples, density per m^2 and percent composition (in parenthesis) in Lower Abbey Pond, 1978.

	Oligochaeta	Hirudinidae	Chaoborus	Chironomidae	Physidae	Planorbitae	Sphaeriidae	Total
4-27								
org/m^2	229		172	362			76	839
% comp.	(27.3)		(20.5)	(43.2)			(9.1)	(100)
5-11								
org/m^2	57			553			19	629
% comp.	(9.1)			(87.9)			(3.0)	(100)
5-22								
org/m^2	534	19	210	1,278		19	820	2,880
% comp.	(18.5)	(.66)	(7.3)	(44.4)		(.66)	(28.5)	(100)
6-1								
org/m^2	76		153	210			896	1,335
% comp.	(5.7)		(11.4)	(15.7)			(67.1)	(100)
6-13								
org/m^2	324		76	401	38		610	1,449
% comp.	(22.4)		(5.3)	(27.6)	(2.6)		(42.1)	(100)
6-22								
org/m^2	229		229	1,354	1,106	610	38	3,566
% comp.	(6.4)		(6.4)	(37.9)	(31.0)	(17.1)	(1.1)	(100)
7-6								
org/m^2	763		439	725	19	19	1,049	3,014
% comp.	(25.3)		(14.6)	(24.1)	(.63)	(.63)	(34.8)	(100)
7-13								
org/m^2	172		38	114			210	534
% comp.	(32.1)		(7.1)	(21.4)			(39.3)	(100)
7-24								
org/m^2	191		1,144	134		19	134	1,622
% comp.	(11.8)		(71.0)	(8.2)		(1.2)	(8.2)	(100)
8-3								
org/m^2	305		57	19	19		134	534
% comp.	(57.1)		(10.7)	(3.6)	(3.6)		(25.0)	(100)
8-15								
org/m^2	38		172				95	305
% comp.	(12.5)		(56.3)				(31.3)	(100)
8-29								
org/m^2	534		153	19	19		362	1,087
% comp.	(49.1)		(14.0)	(1.75)	(1.75)		(33.3)	(100)
9-8								
org/m^2	343						57	400
% comp.	(85.7)						(14.3)	(100)

Table 6. Monthly linear food selectivity indicies for food organisms of rainbow trout (Salmo gairdneri), Lower Abbey Pond, 1978.

Food item	May	June	July
Hydracarina	-	-.71	-
Corixidae	-	+.05	-
Chaoborus	-.04	+.20	-
Chironomidae	-.06	+.31	-
Physidae	-	-.02	-
Sphaeriidae	X	X	+.17

X Present in environmental samples but not in stomachs

\- No index calculated

reflect the behavior of the trout because the rarer a prey species is in the environment, the more likely it has occurred in the stomach by chance (Strauss 1979).

The highest linear food selection index value was +.31 for chironomids during June and the lowest value was also during June with -.71 for Physidae. October food preference may be slightly biased since samples were obtained during a rotenone poisoning operation. Notonectids were found in 85.4% of trout stomachs during the poisoning but had not been previously found in trout stomachs or environmental samples. Notonectids may have been present at that time in greater numbers than on other sampling dates, or they may have been induced into abnormal activity by the rotenone. Large numbers of notonectids were observed flying from the pond when the rotenone was initially applied.

When examining the linear food selection indices, benthic, and meter net data, these assumptions were made: 1) that the random pattern of benthic samples covered all regions and depths of the pond where organisms were present and available to trout, and 2) that the meter net tows covered representative areas of the pond where all organisms present in the pond could be obtained. Two conditions that were found during sampling should also be taken into consideration when examining linear food selection indices and total abundance estimates. Meter net tows were made at night, along shoreline areas with and without riprap, so in areas without riprap estimates of total numbers may have been greater since many organisms such as corixids were observed more frequently and in greater numbers in the interstitial space between rocks. Some benthic samples may have been more representative of the available benthic fauna, as the random pattern of sampling sometimes resulted in sampling sites in deeper zones of the pond which were devoid of dissolved oxygen and thus limiting to the organisms present.

Tables 7-11 show the comparisons between organisms sampled during Eckman dredge or meter net tows and how trout utilized those organisms. These tables are provided to illustrate the food utilization of the trout beyond the linear food selection index calculations. The tables represent those organisms found in Eckman dredge or meter net tow samples during May through September and how those organisms were used by trout.

Chironomids and chaoborids were the most utilized organisms of those occurring in samples. During May, chironomids comprised 52.0% by number of the organisms in benthic samples and 45.9% of the total number of food organisms in trout stomachs. During June chironomids comprised 32.0% by number of the organisms in bottom samples and 34.0% by number of the organisms in stomachs. Also during June, chaoborids comprised 18.0% by number of the organisms occurring in meter net tows or bottom samples and 34.5% of the total food organisms in trout stomachs. During June and July the decapod, *Orconectes virilus*, was the major food item in trout stomachs.

The linear food selection index may not always reflect how fish are utilizing the total resources available to them. In the case of Lower Abbey Pond some organisms such as decapods were not sampled with either the Eckman dredge or meter net but were utilized by the trout. Except for a few instances in June the trout did not utilize organisms that were found in the environmental samples to any great extent.

Table 7. Percent composition comparisons for meter net,* benthic dredge, and stomach contents of rainbow trout (*Salmo gairdneri*) for May 1978, Lower Abbey Pond.

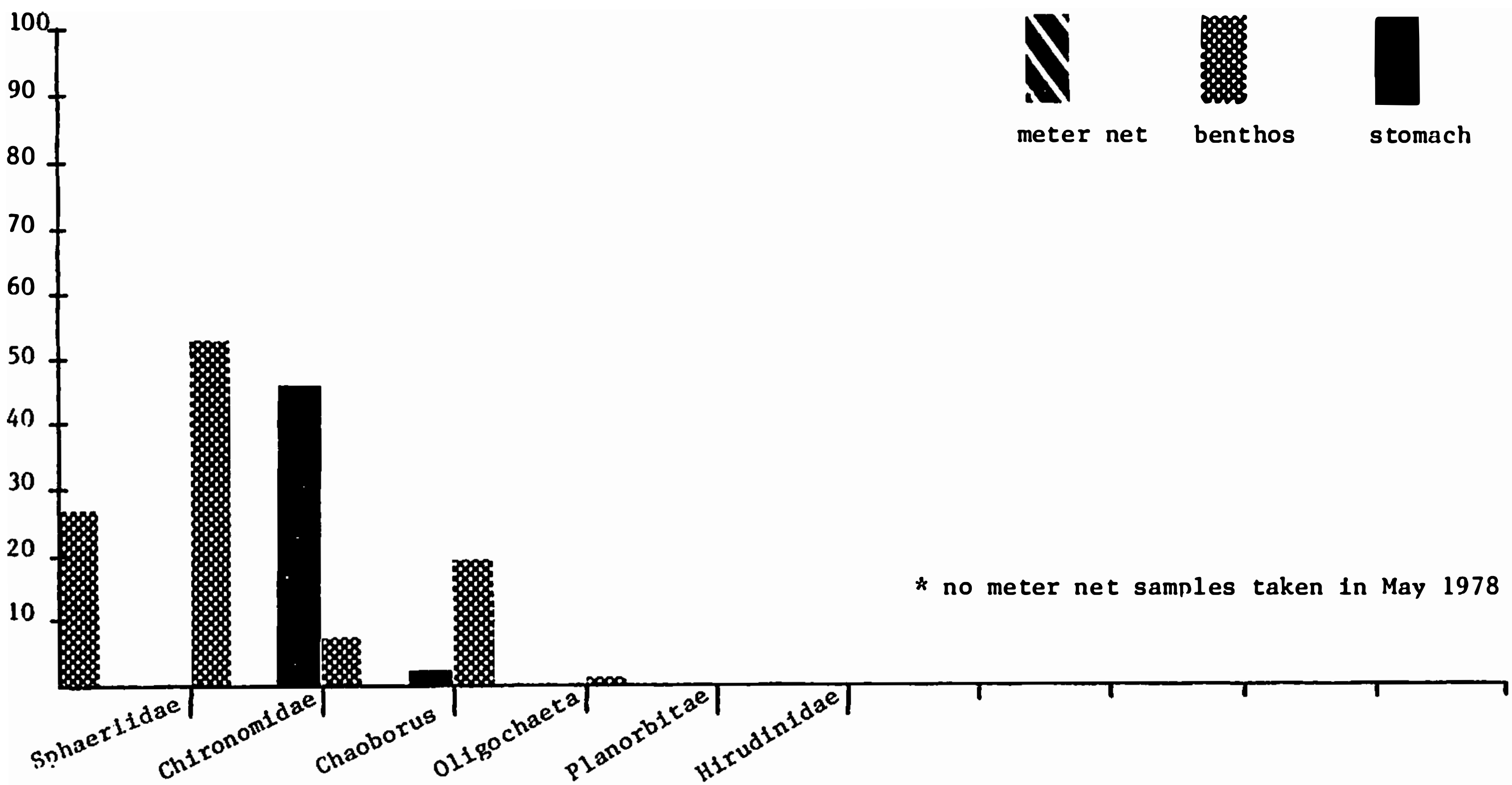


Table 8. Percent composition comparisons for meter net, benthic dredge, and stomach contents of rainbow trout (<u>Salmo gairdneri</u>) for June 1978, Lower Abbey Pond.

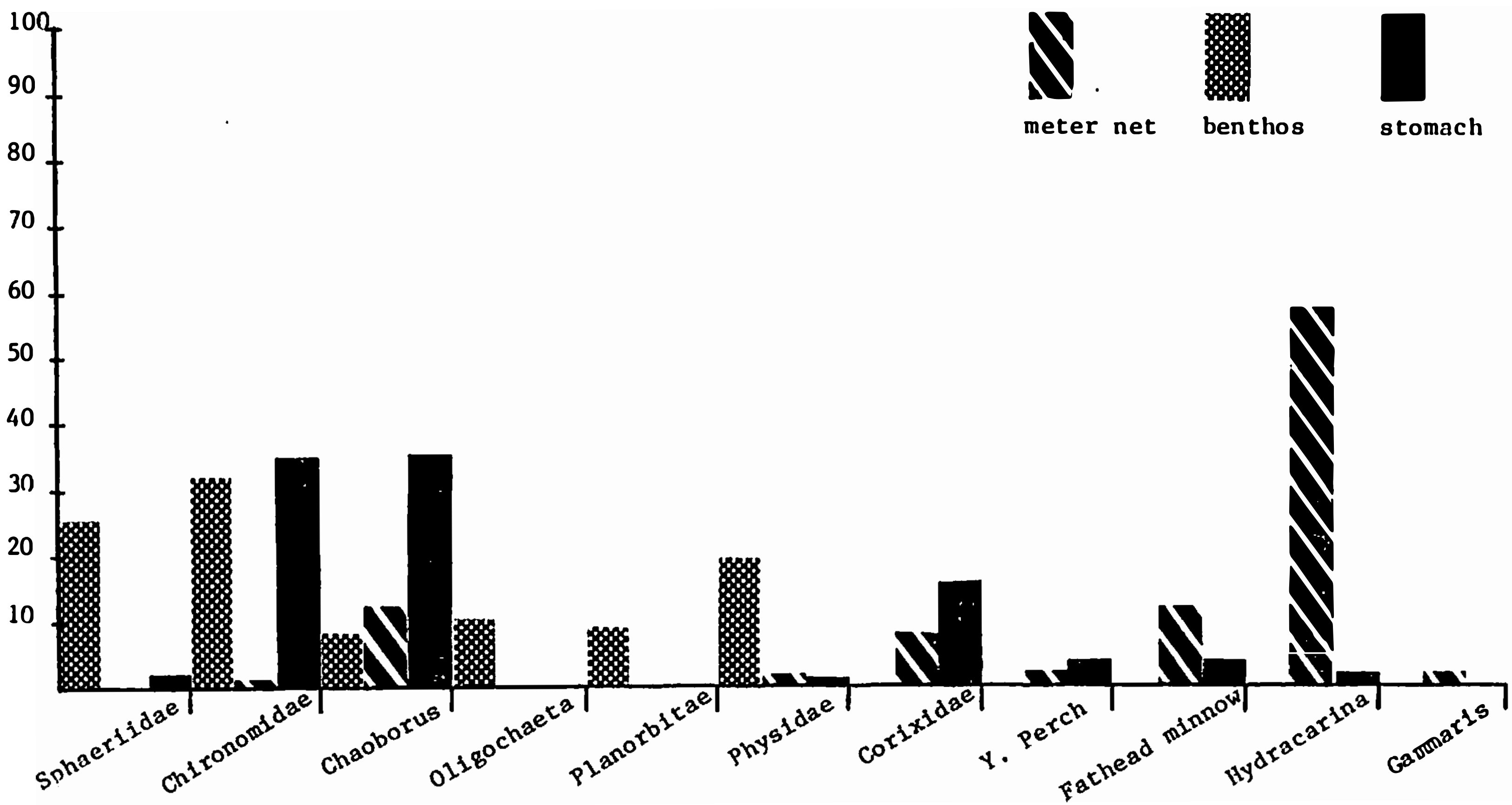


Table 9. Percent composition comparisons for meter net, benthic dredge, and stomach contents of rainbow trout (*Salmo gairdneri*) for July 1978, Lower Abbey Pond.

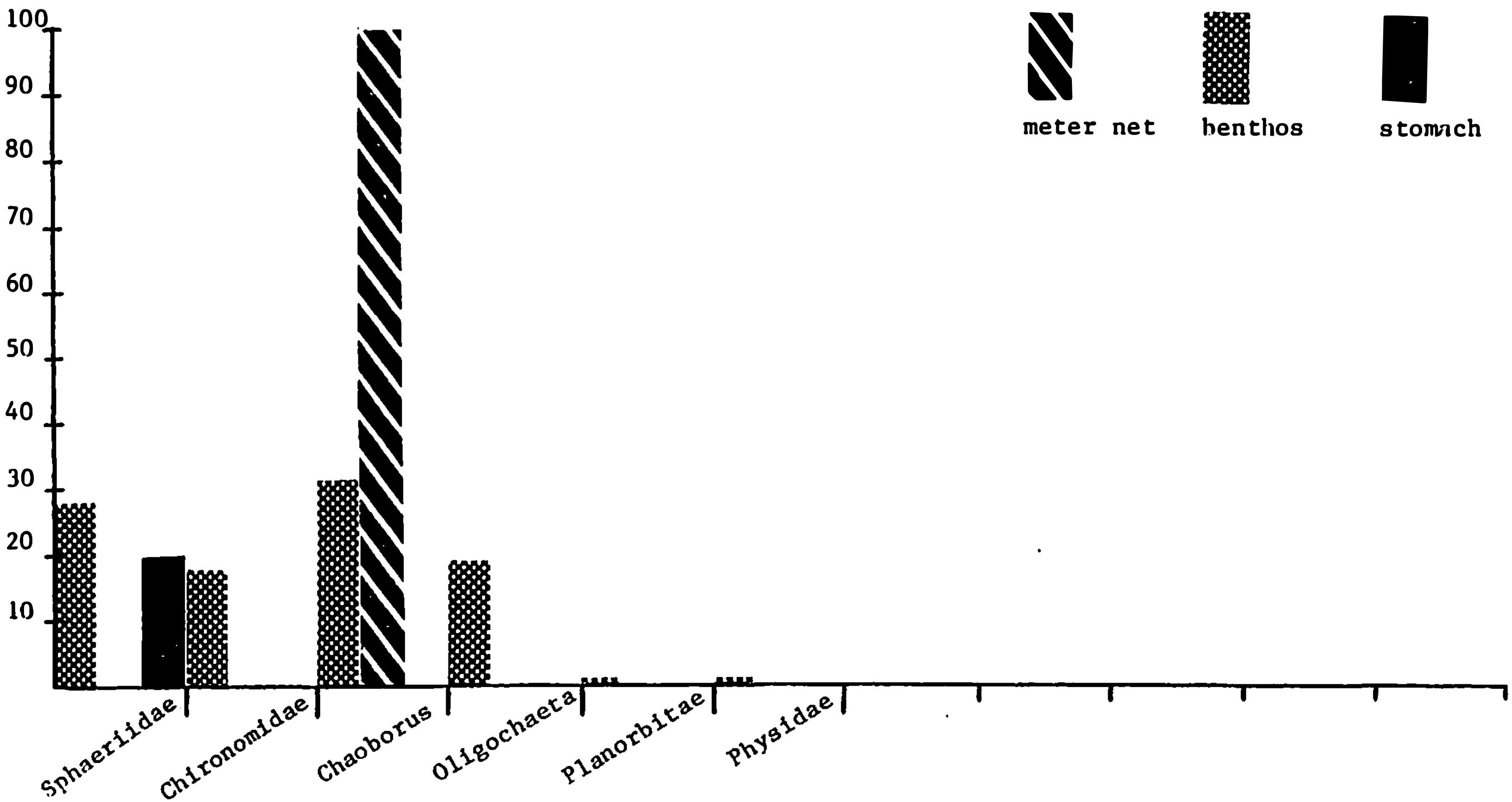


Table 10. Percent composition comparisons for meter net, benthic dredge, and stomach contents of rainbow trout (*Salmo gairdneri*) for August 1978, Lower Abbey Pond.

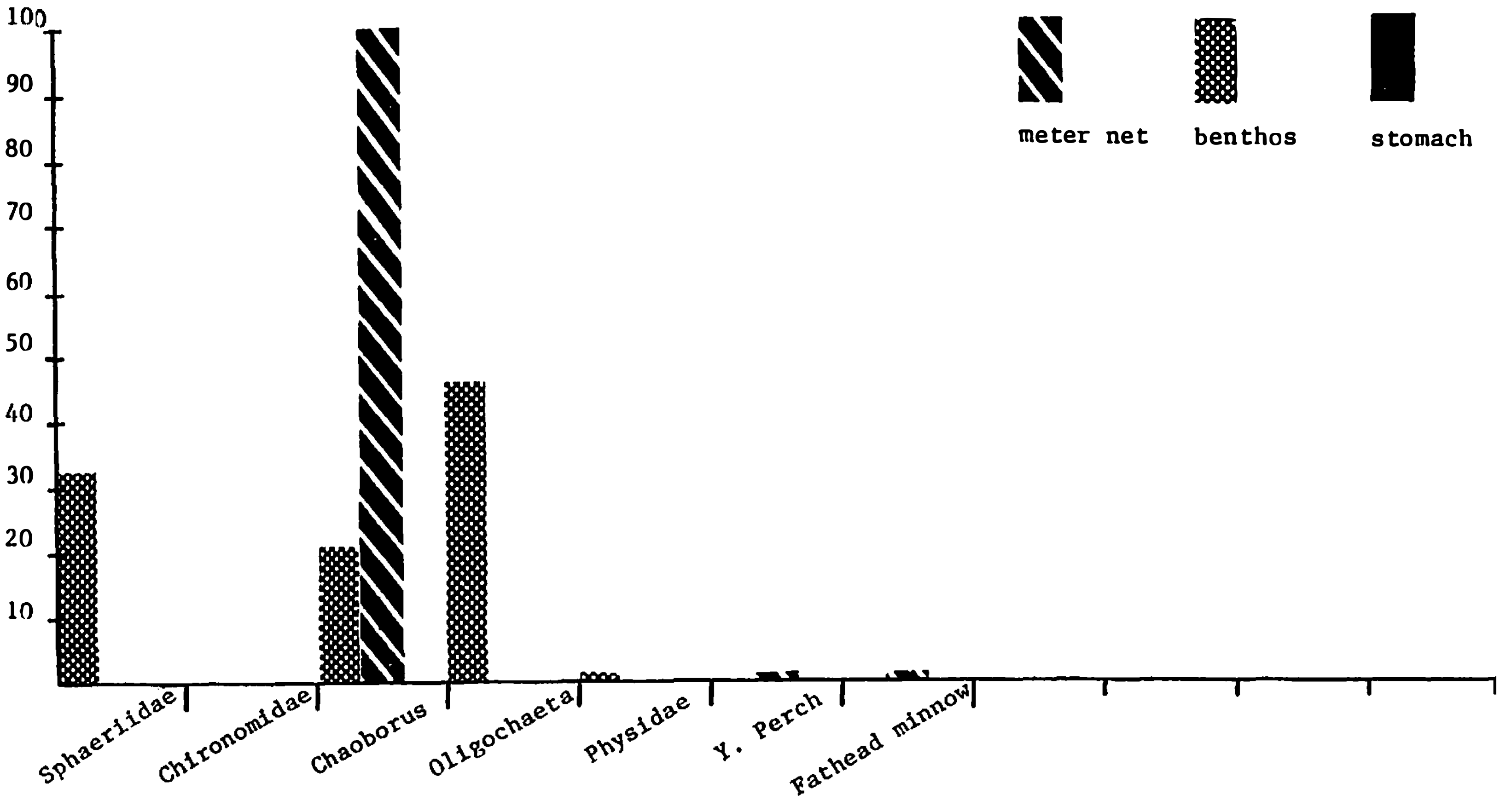
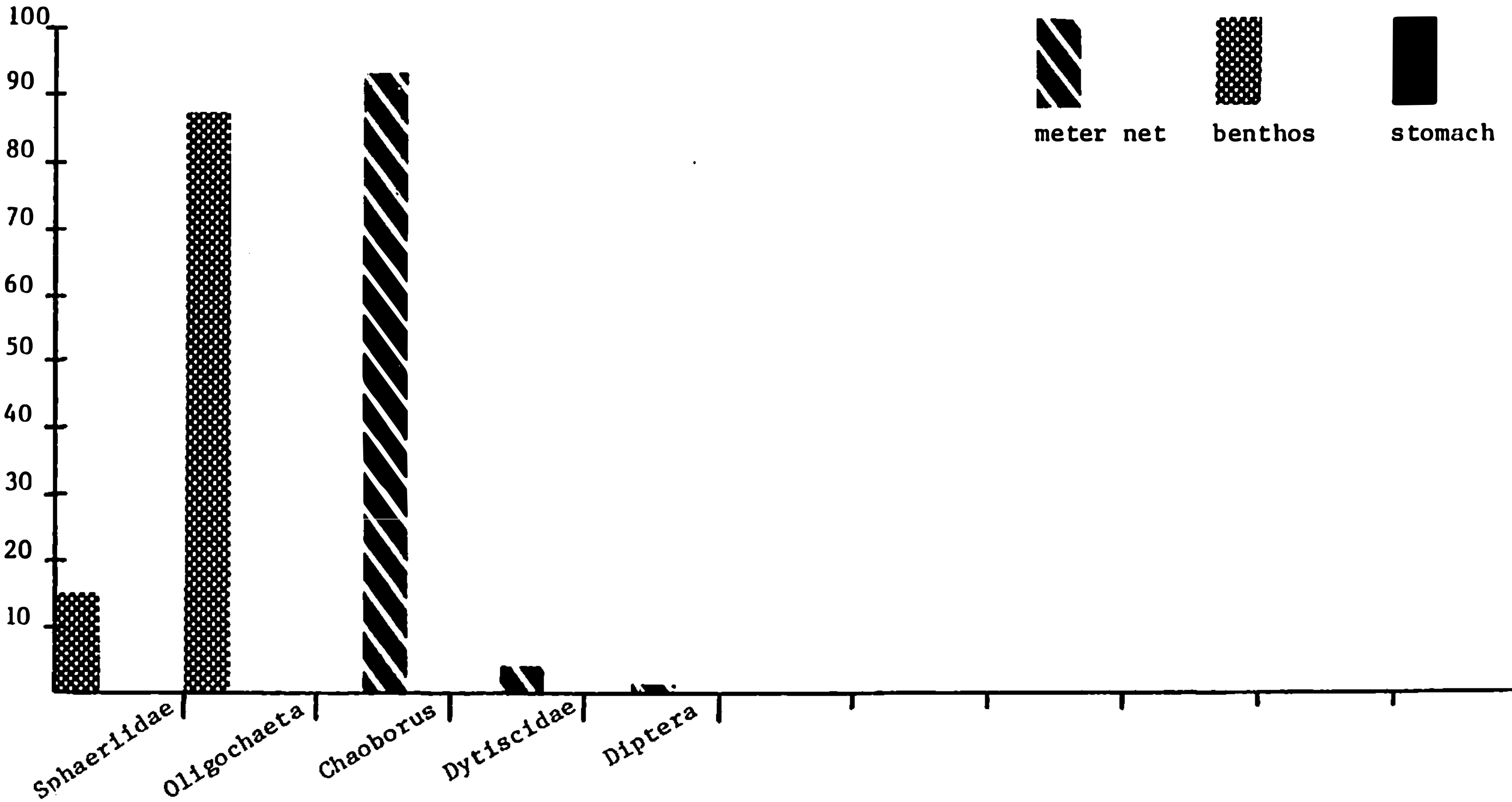


Table 11. Percent composition comparisons for meter net, benthic dredge, and stomach contents of rainbow trout (Salmo gairdneri) for September 1978, Lower Abbey Pond.



This indicates that many organisms that trout were utilizing for food were not effectively sampled for with the equipment used.

Growth

Rainbow trout in the present study had increased to a mean length of 310 mm at 18 months of age. Mean condition [K(TL)] factor for rainbow trout from Lower Abbey Pond was 1.13.

Lengths, weights, and scale measurements taken from 159 rainbow trout collected from January 1978 to October 1978 were used for growth comparisons. Fish were of a known age so all 159 were considered as 1 group. A capture-group distribution was compiled rather than a total length-frequency distribution, since fish were captured over a 10 month period. This capture-group distribution (Table 12) was used to compare growth with other rainbow trout populations.

Growth was greater for Lower Abbey rainbow trout than for rainbow trout stocked in Ontario ponds (McCrimmon and Berest 1961) but less than for trout stocked in North Dakota ponds (Meyers 1973). Lower Abbey Pond rainbow trout were as large or larger than the mean size of similar age-class lake inhabiting rainbow trout from other areas (Carlander 1969) throughout the study period. At 9 months of age, the rainbow trout of Lower Abbey Pond had a mean length of 175 mm whereas rainbow trout 9 months of age in Weber Lake, Wisconsin, had a mean length of 155 mm (Burdick and Cooper 1956). Rainbow trout in Lower Abbey Pond had increased to a mean length of 310 mm at 18 months of age. Rainbow trout data available in Carlander (1969) indicated that most rainbow trout throughout the country increased to a mean length of over 300 mm only

Table 12. Capture-group distribution for rainbow trout (Salmo gairdneri), Lower Abbey Pond, 1978.

Date	Length range	No.	$\bar{x}$ length	$\bar{x}$ weight	$\bar{x}$ scale radius	$\bar{x}$ k-factor
1 - 5	155.0 - 245.0	23	175.0	63.3	30.9	1.06
2 - 16	155.0 - 243.0	11	181.3	62.0	29.0	.98
3 - 16	151.0 - 192.0	6	167.5	46.7	31.3	.97
4 - 27	162.0 - 205.0	5	179.2	61.2	23.6	1.04
5 - 12	173.0 - 248.0	16	201.3	88.5	32.2	1.04
5 - 22	172.0 - 305.0	18	226.1	123.0	38.1	1.02
6 - 1	170.0 - 335.5	20	231.5	163.4	40.2	1.30
6 - 13	145.0 - 331.0	19	232.0	168.6	42.3	1.42
6 - 22	200.0 - 280.0	13	233.2	154.3	42.4	1.18
7 - 6	235.0 - 300.0	7	269.3	213.1	49.9	1.06
7 - 14	334.0 - 335.0	2	334.5	525.0	69.5	1.40
7 - 24	245.0 - 275.0	2	260.0	199.0	46.5	1.12
8 - 3	285.0	1	285.0	374.0	51.0	1.60
8 - 14	265.0 - 315.0	2	290.0	247.0	52.5	.96
10 - 11	272.0 - 352.0	14	310.1	344.1	56.4	1.14

when nearing age II or 24 months. From these comparisons it was evident that Lower Abbey rainbow trout exhibited good growth.

The mean [K(TL)] value derived from Carline et al. (1976) for 19 month old rainbow trout was .88, lower than that of Lower Abbey rainbows. Data derived from Meyers and Peterka (1976) indicated that rainbow trout from 4 prairie lakes in North Dakota had a mean [K(TL)] value of 1.64, higher than that of Lower Abbey rainbows. They worked in shallow highly productive lakes which might explain the difference in growth that would account for the higher [K(TL)] value. High condition is usually associated with rapid growth (Bennett 1948) but in some locations relatively rapid growth is associated with moderately low condition (Bennett 1970). Lower Abbey rainbows may fall into the latter category. Lower Abbey rainbows may have also had competition from other fish species present in the pond; this could have lowered the [K(TL)] value for the trout.

Climatic conditions probably did not seriously influence growth of rainbow trout in Lower Abbey Pond. Data from Canadian studies (Lawler et al. 1974) indicate that good rainbow trout growth is possible at least up to latitude $50^{\circ}30'$ N.

Good growth of the Lower Abbey rainbow trout may be explained in part by the apparent low standing crop of fishes present in the pond. During rotenone poisoning in October 1978 a total weight of 15.34 kg/ha of all fish was found. Rainbow trout contributed 1.77 kg/ha of the total weight and the remainder was comprised of pumpkinseeds (*Lepomis gibbosus*), fathead minnows, yellow perch (*Perca flavescens*), yellow bullheads (*Ictalurus natalis*), and bluegills (*L. macrochirus*).

During the course of the study only 159 (7.6%) of 2,075 stocked rainbow trout were recovered. Seven walleye were captured during May and July 1978, but none were recovered when the pond was toxified with rotenone.

Some type of natural mortality during the study could have resulted in this fish loss, however, no dead or dying fishes were ever observed in the pond. Since sampling periods were at 10 day intervals and abbey personnel frequently observed the pond, any gross fish die-off would probably have been observed. The most probable explanation for the low fish recovery rates was loss of the fishes via the unscreened drain tube during high water levels in the spring of 1978. Lewis (1950) stated that such losses can occur. Other fish species present may have also exited the pond via the drain tube but since no initial population numbers were known for them, no estimate can be made of losses. This loss of fish, trout included, could have affected the growth and condition of the remaining trout. If the reduction in fish numbers occurred early in the year the remaining trout may have had the advantage of reduced competition but if the reduction occurred further into the study the trout collected during rotenone poisoning would probably represent the average size present. In addition, it cannot be assumed that trout growth would increase with decreased trout numbers since competition may not have been present at the higher population levels. Upon my recommendation the drain tube has been screened to prevent possible fish loss.

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APPENDIX

Appendix I. Chemical parameters for Lower Abbey Pond, 1977.

	Sampling depth[1]	Date:	6-22			7-7			7-20	
		Station: 1	2	3	1	2	3	1	2	3
Dissolved O_2 mg/l	S[2]	7.0	7.0	7.1	8.0	8.0	8.6	7.3	7.4	7.5
	2	7.0	6.9	7.1	8.0	7.9	8.6	8.3	7.3	7.5
	4	6.8	6.7	7.2	<u>3.7</u>[3] 6.8	6.7	7.1	<u>3.8</u> 7.5	6.5	7.6
	6	<u>4.4</u> 7.1	4.9	4.9	-	.4	3.4	-	0	1.3
	8	-	<u>6.5</u> 0	<u>8.2</u> 0	-	<u>6.7</u> 0	0	-	<u>7.0</u> 0	0
	10	-	-	-	-	-	-	-	-	-
Temp. (°C)	S	19	19	18.5	25	26	24	25	25	25
	2	19	19	18.5	26	25	25	25	25	25
	4	18.5	14	18	<u>3.7</u> 23	22	21	<u>3.8</u> 25	24	24
	6	<u>4.4</u> 18.5	12	13.5	-	18	17	-	17.5	18
	8	-	<u>6.5</u> 12	8.5	-	<u>6.7</u> 14	10	-	<u>7.0</u> 14	12
	10	-	-	<u>8.2</u> 7.5	-	-	-	-	-	-
pH	S	6.8	6.7	6.8	7.4	7.0	6.9	6.7	6.8	6.7
Total alkalinity mg/l	S	130	120	120	150	150	140	140	130	130
Total hardness mg/l	S	160	165	170	170	180	170	190	190	190
Conductivity (μmhos)	S	-	-	-	-	-	-	350	355	400

Appendix 1. Continued

	Sampling depth	Date: 8-3 Station: 1	2	3	8-15 1	2	3	9-16 1	2	3
Dissolved O_2 mg/l	S	5.6	5.8	5.9	5.0	3.9	3.7	3.6	4.6	4.7
	2	6.7	5.9	5.8	4.6	4.1	3.7	4.1	3.9	4.7
	4	4.1	4.3	4.8	4.2	4.6	4.7	4.0	4.4	5.2
	6	$\frac{5.5}{3.9}$	0	1.6	$\frac{4.4}{3.8}$	3.0	1.7	$\frac{4.7}{3.7}$	4.6	5.2
	8	-	$\frac{6.9}{0}$	0	-	$\frac{6.5}{2.1}$	$\frac{7.9}{0}$	-	$\frac{7.0}{4.4}$	$\frac{8.2}{1.3}$
	10	-	-	-	-	-	-	-	-	-
Temp. (°C)	S	22	22	22	20	20	20	22	22	22
	2	22	21	22	20	20	20	22	22	22
	4	21	21	21	20	20	20	22	22	22
	6	$\frac{5.5}{21}$	18	18	$\frac{4.4}{20}$	19	19	$\frac{4.7}{22}$	22	22
	8	-	$\frac{6.9}{15}$	13	-	$\frac{6.5}{19}$	$\frac{7.9}{18}$	-	$\frac{7.0}{22}$	$\frac{8.2}{22}$
	10	-	-	-	-	-	-	-	-	-
pH	S	7.2	7.0	7.1	6.8	6.6	6.6	6.7	6.6	6.7
Total alkalinity mg/l	S	140	140	140	120	130	130	145	155	150
Total hardness mg/l	S	230	190	190	180	180	180	190	190	190
Conductivity (µmhos)	S	335	346	356	330	330	330	316	321	321

Appendix 1. Continued

	Sampling depth	Date: Station:	10-14 1	2	3
Dissolved O_2 mg/l	S		5.7	5.8	5.9
	2		5.5	5.6	6.3
	4		5.6	5.6	5.8
			4.6		
	6		5.3	5.8	5.9
				7.1	7.9
	8		-	6.0	5.7
	10		-	-	-
Temp. (°C)	S		9	8.5	8.0
	2		8.5	8.0	8.0
	4		8.0	8.0	8.0
			4.6		
	6		8.0	7.5	8.0
				7.1	7.9
	8		-	7.0	8.0
	10		-	-	-
pH	S		6.1	6.5	6.5
Total alkalinity mg/l	S		140	140	210
Total hardness mg/l	S		190	190	180
Conductivity (µmhos)	S		336	336	336

[1] Depth in meters

[2] Surface

[3] Underlined values are actual bottom depths

Appendix 2. Chemical parameters for Lower Abbey Pond, 1978.

	Sampling depth[1]	Date: Station:	1-5			2-16			3-17		
			1	2	3	1	2	3	1	2	3
Dissolved O_2 mg/l	S		6.5	7.0	6.0	5.7	4.6	4.7	10.3	10.2	9.9
	2		6.5	6.0	6.0	5.0	4.5	4.4	9.8	9.4	9.9
			3.4			3.6			3.8		
	4		6.5	6.1	6.0	5.1	4.3	4.0	9.0	7.9	8.5
	6		-	5.0	4.4	-	3.2	2.0	-	3.1	2.1
				6.9	8.5		7.7	7.1		6.5	7.8
	8		-	3.0	2.4	-	1.9	1.0	-	2.5	.5
Temp. (°C)	S		1.0	1.0	1.0	1.5	2.0	2.0	2.0	2.0	1.0
	2		2.0	1.0	1.0	2.0	3.0	2.0	2.5	2.5	3.0
			3.4			3.6			3.8		
	4		2.0	2.0	2.0	2.5	2.5	3.0	3.0	3.0	3.0
	6		-	2.5	2.5	-	3.0	4.0	-	4.0	4.0
				6.9	8.5		7.7	7.1		6.5	7.8
	8		-	2.5	3.0	-	4.0	4.0	-	4.0	4.5
pH	S		6.6	6.6	6.8	7.2	8.2	7.0	7.5	7.2	7.3
Total alkalinity mg/l	S		150	150	160	180	180	180	220	180	180
Total hardness mg/l	S		200	210	220	195	195	195	240	230	230
Conductivity (μmhos)	S		374	374	374	408	408	408	450	450	442
Secchi disk visibility (cm)			-	-	-	-	-	-	-	-	-

Appendix 2. Continued

	Sampling depth	Date:	4-27			5-12			5-23		
		Station:	1	2	3	1	2	3	1	2	3
Dissolved O_2 mg/l	S		17.2	16.6	16.1	9.9	9.4	9.4	6.9	6.9	6.6
	2		16.6	15.8	16.1	9.4	9.6	9.4	6.5	6.4	6.9
	4		15.6	13.5	14.5	3.5/8.9	8.9	8.6	2.5/6.9	5.2	5.7
	6		4.2/15.6	13.2	11.9	-	8.4	8.3	-	1.5	1.6
	8		-	8.2/11.0	11.2	-	7.3/3.1	8.1/2.0	-	7.4/.1	8.1/.2
Temp. (°C)	S		10	11	10	13	13	13	19	19	19
	2		9	10	9	13	13	12	18	18.5	18.5
	4		8	7	7	3.5/13	12	12	2.5/18	13	15
	6		4.2/8	6	6	-	10	11	-	11	11
	8		-	8.2/6	6	-	7.3/7	8.1/6	-	7.4/8	8.1/7.5
pH	S		9.3	9.3	9.3	9.0	9.0	9.0	7.6	7.6	7.4
Total alkalinity mg/l	S		110	130	130	120	115	110	150	150	130
Total hardness mg/l	S		195	190	195	180	170	190	200	200	180
Conductivity (µmhos)	S		548	343	356	351	351	351	341	352	352
Secchi disk visibility (cm)			55.9	60.9	60.9	76.2	76.2	76.2	147.2	152.4	152.4

Appendix 2. Continued

	Sampling depth	Date:	6-1			6-13			6-23		
		Station:	1	2	3	1	2	3	1	2	3
Dissolved O_2 mg/l	S		6.6	6.6	6.6	7.9	7.9	7.6	7.5	7.4	7.5
	2		-	-	-	7.8	7.6	7.3	7.7	7.5	7.7
	4		-	-	-	3.8/7.5	5.2	5.8	2.3/7.2	6.0	5.0
	6		-	-	-	-	3.8	8.7/3.0	-	2.5	4.5
	8		-	-	-	-	8.5/0	8.7/0	-	7.1/.1	.3
Temp. (°C)	S		16	16	16	21	20	20	22	21	22
	2		16	16	16	20	20	20	22	21	21
	4		3.0/16	16	16	3.8/20	18	18	2.3/21	19	19
	6		-	10	10	-	16	16	-	17	17
	8		-	7.5/8	8.4/8	-	8.5/8	8.7/9	-	7.1/11	10
pH	S		7.5	7.5	7.5	7.6	8.4	8.4	9.1	9.2	9.2
Total alkalinity mg/l	S		150	150	170	140	150	160	110	130	150
Total hardness mg/l	S		200	200	140	180	190	210	190	200	220
Conductivity (μmhos)	S		387	387	387	371	371	371	360	371	371
Secchi disk visibility (cm)			121.9	116.8	116.8	152.4	152.4	152.4	121.9	121.9	121.9

Appendix 2. Continued

	Sampling depth	Date: Station:	7-6 1	7-6 2	7-6 3	7-14 1	7-14 2	7-14 3	7-25 1	7-25 2	7-25 3
Dissolved O_2 mg/l	S		6.2	6.2	6.2	6.3	6.3	6.3	6.2	5.8	5.8
	2		5.7	6.2	5.0	6.3	6.3	6.3	5.8	5.8	5.8
	4		2.9/5.2	2.0	3.1	3.2/5.8	5.4	5.7	3.6/5.7	5.6	5.2
	6		-	.5	.2	-	0	.5	-	2.9	5.6
	8		-	7.8/0	7.5/0	-	8.8/0	8.4/0	-	7.5/0	0
Temp. (°C)	S		25	25	25	23	23	23	22	22	22
	2		25	25	25	22	23	23	22	22	22
	4		2.9/24	20	20	3.2/22	22	22	3.6/22	22	22
	6		-	15	16	-	15	15	-	15	15
	8		-	7.8/10	7.5/11	-	8.8/9	8.4/10	-	7.5/11	10
pH	S		9.2	8.9	9.1	8.9	9.6	9.0	8.7	8.8	8.9
Total alkalinity mg/l	S		120	140	140	120	150	150	110	125	125
Total hardness mg/l	S		190	190	180	180	210	200	205	190	190
Conductivity (μmhos)	S		345	355	360	357	366	373	360	371	360
Secchi disk visibility (cm)			121.9	139.7	131.2	121.9	152.4	147.3	121.9	121.9	106.7

Appendix 2. Continued

	Sampling depth	Date: Station:	8-4 1	8-4 2	8-4 3	8-15 1	8-15 2	8-15 3	8-29 1	8-29 2	8-29 3
Dissolved O_2 mg/l	S		6.1	6.1	6.1	5.7	5.7	5.4	6.3	6.0	6.2
	2		6.1	6.1	6.1	5.5	5.6	5.8	6.1	6.2	6.1
			2.5			3.0			3.2		
	4		6.0	6.2	6.2	5.2	5.8	5.4	5.5	6.2	6.1
	6		-	4.2	4.3	-	2.0	.3	-	3.8	5.3
				8.5	7.5		8.8	8.0		8.9	8.3
	8		-	0	0	-	0	0	-	0	0
Temp. (°C)	S		21	21	21	24	24	24	20	20	20
	2		20	21	20	24	24	24	20	20	20
			2.5			3.0			3.2		
	4		20	20	20	24	24	24	20	20	20
	6		-	18	16	-	17	17	-	19	19
				8.5	7.5		8.8	8.0		8.9	8.3
	8		-	10	11	-	10	11	-	12	12
pH	S		9.0	9.0	8.8	8.8	8.6	8.7	8.6	8.3	8.3
Total alkalinity mg/l	S		150	140	130	130	140	150	140	150	140
Total hardness mg/l	S		200	180	190	200	200	220	210	190	200
Conductivity (μmhos)	S		335	356	367	374	374	379	363	374	374
Secchi disk visibility (cm)			121.9	121.9	121.9	106.7	106.7	106.7	76.2	76.2	76.2

Appendix 2. Continued

	Sampling depth	Date:	9-8			9-29		
		Station:	1	2	3	1	2	3
Dissolved O_2 mg/l	S		6.1	6.1	6.1	7.0	6.2	7.3
	2		6.2	5.8	5.7	6.7	7.2	6.3
	4		3.3 5.9	5.9	5.6	2.6 5.9	7.2	7.2
	6		-	5.7	5.5	-	6.4	7.2
	8		-	7.2 1.8	9.3 0	-	8.7 5.6	7.8 5.1
Temp. (°C)	S		22.5	22.5	22.5	15	15	15
	2		22.5	22.5	22.5	15	15	15
	4		3.3 22.5	22.5	22.5	2.6 15	15	15
	6		-	22	22	-	15	15
	8		-	7.2 20	9.3 12.5	-	8.7 15	7.8 15
pH	S		8.5	8.5	8.5	9.1	8.7	9.1
Total alkalinity mg/l	S		120	135	140	130	125	130
Total hardness mg/l	S		180	175	190	180	190	180
Conductivity (µmhos)	S		-	-	-	366	366	366
Secchi disk visibility (cm)			106.7	106.7	106.7	106.7	106.7	106.7

[1] Depth in meters

[2] Surface

[3] Underlined values are actual bottom depths

Appendix 3. Density per liter and percent abundance (in parenthesis) of zooplankton in Lower Abbey Pond, 1978.

	4-27 Tow 1	4-27 Tow 2	4-27 Tow 3	4-27 Tow 4	5-12 Tow 1	5-12 Tow 2	5-12 Tow 3	5-12 Tow 4
Crustacea								
Cladocera								
Daphnia galeata	T[1] (2.7)	T[1] (3.4)	T[1] (8.3)	T[1] (2.3)	T[1] (1.8)	T[1] (2.8)	T[1] (1.5)	T[1] (3.3)
Daphnia ambigua	-	-	-	-	-	-	-	-
Daphnia parvula	-	-	-	-	-	-	-	-
Bosmina longirostrus	T[1] (10.8)	T[1] (35.0)	T[1] (11.0)	T[1] (9.4)	.83 (27.0)	.33 (25.0)	.32 (22.3)	.22 (9.4)
Diaphanosoma sp.	-	-	-	-	-	-	-	-
Copepoda								
Cyclopoid sp.	.1 (77.0)	T[1] (35.0)	.12 (72.3)	.33 (84.0)	2.1 (69.0)	.88 (64.6)	1.0 (72.0)	1.9 (82.0)
Nauphlii	T[1] (8.1)	T[1] (28.0)	T[1] (8.3)	T[1] (4.6)	T[1] (2.3)	.1 (7.9)	T[1] (3.4)	.12 (5.1)
Calanoid sp.	T[1] (2.7)	-	-	-	T[1] T[2]	-	T[1] (.37)	-
Total Density/Liter	.14	.13	.18	.40	3.1	1.4	1.4	2.3

Appendix 3. Continued

	5-23				6-1			
	Tow 1	Tow 2	Tow 3	Tow 4	Tow 1	Tow 2	Tow 3	Tow 4
Crustacea								
Cladocera								
<u>Daphnia galeata</u>	T[1] T[2]	T[1] T[2]	T[1] T[2]	T[1] T[2]	1.3 (11.5)	.8 (13.0)	.74 (9.7)	.7 (8.1)
<u>Daphnia ambigua</u>	T[1] T[2]	T[1] T[2]	T[1] T[2]	T[1] T[2]	2.1 (18.3)	.7 (11.2)	.79 (10.4)	.38 (4.4)
<u>Daphnia parvula</u>	T[1] T[2]	T[1] T[2]	T[1] T[2]	T[1] T[2]	1.0 (9.1)	.34 (5.6)	.4 (5.2)	.19 (2.2)
<u>Bosmina</u> <u>longirostrus</u>	2.4 (39.6)	1.0 (25.0)	.44 (18.2)	.71 (19.8)	1.3 (11.9)	1.3 (21.0)	1.5 (20.0)	1.7 (19.9)
<u>Diaphanosoma</u> sp.	T[1] T[2]	T[1] T[2]	-	T[1] T[2]	T[1] T[2]	-	-	-
Copepoda								
<u>Cyclopoid</u> sp.	3.6 (58.0)	2.9 (70.0)	1.8 (77.0)	2.7 (75.6)	5.49 (48.0)	2.9 (48.0)	4.1 (54.0)	5.5 (63.0)
Nauphlii	T[1] T[2]	T[1] (3.0)	T[1] (2.3)	T[1] (1.6)	T[1] T[2]	T[1] T[2]	T[1] (1.1)	.2 (2.6)
<u>Calanoid</u> sp.	-	T[1] T[2]	-	-	-	-	-	-
Total Density/Liter	6.1	4.1	2.4	3.6	11.2	6.2	7.6	8.7

Appendix 3. Continued

	6-5				6-12			
	Tow 1	Tow 2	Tow 3	Tow 4	Tow 1	Tow 2	Tow 3	Tow 4
Crustacea								
Cladocera								
Daphnia galeata	T[1] (4.8)	.5 (14.0)	T[1] T[2]	.17 (8.1)	1.7 (22.6)	1.1 (21.0)	.56 (7.2)	.41 (6.5)
Daphnia ambigua	.36 (12.1)	.4 (11.2)	.24 (6.8)	.19 (9.1)	1.2 (15.8)	1.1 (21.0)	2.5 (32.5)	2.4 (38.0)
Daphnia parvula	.2 (6.0)	.2 (5.6)	.12 (3.4)	T[1] (4.5)	.59 (7.9)	.56 (10.3)	1.2 (16.2)	1.2 (19.0)
Bosmina longirostrus	1.7 (57.6)	1.2 (32.0)	2.1 (60.0)	.73 (35.0)	1.9 (25.0)	1.0 (18.5)	2.1 (27.6)	.68 (11.0)
Diaphanosoma sp.	-	-	-	-	-	-	-	-
Copepoda								
Cyclopoid sp.	.6 (19.0)	1.3 (35.0)	.56 (15.9)	.86 (41.0)	2.0 (27.4)	1.4 (26.0)	1.1 (13.9)	1.5 (23.7)
Nauphlii	T[1] T[2]	T[1] T[2]	.49 (13.8)	-	T[1] (1.0)	.24 (4.4)	.2 (2.5)	T[1] (1.3)
Calanoid sp.	T[1] T[2]	T[1] (1.4)	-	T[1] (2.6)	-	-	-	-
Total Density/Liter	3.0	3.7	3.6	2.1	5.7	5.4	7.6	6.3

Appendix 3. Continued

	6-22				7-13			
	Tow 1	Tow 2	Tow 3	Tow 4	Tow 1	Tow 2	Tow 3	Tow 4
Crustacea								
Cladocera								
Daphnia galeata	1.0	.38	.13	.33	T[1]	T[1]	.19	.13
	(21.5)	(10.2)	(5.9)	(7.4)	(2.1)	(11.0)	(14.4)	(7.2)
Daphnia ambigua	.87	1.2	.75	1.4	T[1]	T[1]	.13	.19
	(17.6)	(32.0)	(33.0)	(31.0)	(10.1)	(12.3)	(9.6)	(10.5)
Daphnia parvula	.41	.60	.38	.69	T[1]	T[1]	T[1]	T[1]
	(8.8)	(16.0)	(16.5)	(15.7)	(4.9)	(6.2)	(4.7)	(5.2)
Bosmina longirostrus	.88	.37	.31	.33	.58	.35	.86	1.1
	(18.0)	(9.9)	(13.7)	(7.6)	(66.4)	(65.0)	(64.0)	(62.7)
Diaphanosoma sp.	-	-	-	-	-	-	-	-
Copepoda								
Cyclopoid sp.	1.25	1.0	.64	1.4	T[1]	T[1]	.24	.2
	(27.0)	(28.0)	(28.0)	(33.0)	(11.0)	(5.9)	(18.0)	(12.0)
Nauphlii	.35	.14	T[1]	.19	T[1]	-	T[1]	T[1]
	7.5	(3.8)	2.4	4.2	(5.8)		2.4	(2.4)
Calanoid sp.	-	-	T[1]	T[1]	-	-	T[1]	-
			T[2]	T[2]			T[2]	
Total Density/Liter	4.9	3.7	2.3	4.4	.88	.54	1.5	1.8

Appendix 3. Continued

	8-14				8-29			
	Tow 1	Tow 2	Tow 3	Tow 4	Tow 1	Tow 2	Tow 3	Tow 4
Crustacea								
Cladocera								
Daphnia galeata	-	-	-	-	T^1 T^2	-	-	-
Daphnia ambigua	T^1 (4.1)	-	-	T^1 T^2	T^1 2.1	T^1 T^2	T^1 (1.9)	- -
Daphnia parvula	T^1 (2.1)	-	-	T^1 T^2	T^1 1.0	T^1 T^2	T^1 T^2	-
Bosmina longirostrus	T^1 (6.2)	.21 (65.0)	1.0 (58.4)	1.7 71	1.7 (72.0)	4.3 (90.0)	3.5 (86.0)	-
Diaphanosoma sp.	-	-	-	-	-	-	-	-
Copepoda								
Cyclopoid sp.	-	T^1 (6.5)	.2 (12.0)	.18 (7.5)	.48 (19.8)	.36 (7.5)	.40 (9.8)	-
Nauphlii	T^1 (87.6)	T^1 (28.0)	.5 (30.0)	.49 (20.0)	T^1 (4.0)	T^1 T^2	T^1 1.6	-
Calanoid sp.	-	-	T^1 T^2	-	T^1 T^2	T^1 T^2	T^1 T^2	-
Total Density/Liter	.1	.33	1.7	2.4	2.4	4.8	4.1	-

Appendix 3. Continued

	9-6				9-28			
	Tow 1	Tow 2	Tow 3	Tow 4	Tow 1	Tow 2	Tow 3	Tow 4
Crustacea								
Cladocera								
<u>Daphnia galeata</u>	T^1 T^2	-	T^1 T^2	-	T^1 T^2	T^1 T^2	T^1 T^2	T^1 T^2
<u>Daphnia ambigua</u>	T^1 (1.1)	T^1 T^2	T^1 (2.9)	T^1 (3.3)	.14 (2.5)	T^1 (1.1)	.21 (4.3)	.2 (4.4)
<u>Daphnia parvula</u>	T^1 T^2	T^1 T^2	T^1 (1.5)	T^1 (1.6)	T^1 (1.3)	T^1 T^2	.1 (2.2)	T^1 (2.2)
<u>Bosmina</u> <u>longirostrus</u>	3.5 (70.0)	1.3 (59.0)	1.4 (53.0)	1.1 (44.0)	4.3 (78.8)	3.8 (74.0)	2.9 (60.0)	1.9 (56.0)
<u>Diaphanosoma</u> sp.	-	-	-	T^1 T^2	-	-	-	-
Copepoda								
<u>Cyclopoid</u> sp.	.80 (15.6)	.46 (21.0)	.69 (27.0)	.95 (40.0)	.84 (15.2)	1.1 (22.0)	1.5 (31.0)	1.2 (33.0)
Nauphlii	.59 (11.7)	.33 (15.3)	.34 (13.0)	.22 (9.2)	T^1 T^2	T^1 (1.1)	T^1 T^2	T^1 (1.4)
<u>Calanoid</u> sp.	T^1 T^2	T^1 (3.1)	T^1 (2.6)	T^1 (1.1)	T^1 (1.1)	T^1 T^2	T^1 T^2	T^1 (2.2)
Total Density/Liter	5.1	2.2	2.6	2.4	5.5	5.1	4.8	3.4

T^1 - less than .1 org/liter
T^2 - less than 1% org/liter